

IN-SITU PROPELLANT PRODUCTION ON MARS: A SABATIER/ELECTROLYSIS DEMONSTRATION PLANT. David L. Clark, Lockheed Martin Astronautics, Denver Colorado 80201, USA.

An efficient, reliable propellant production plant has been developed for use on Mars. Using a Sabatier reactor in conjunction with a water electrolysis system, a complete demonstration plant has produced methane and liquid oxygen from simulated Martian atmosphere. The production plant has demonstrated high efficiency, extended duration production and autonomous operations. This paper presents the results and conclusions relating to eventual use in a Mars sample return mission. This work was funded by the Jet Propulsion Laboratory (JPL). The production plant was built and tested at the Propulsion Center of Lockheed Martin at the Denver Colorado facility.

In order to reduce launch mass for missions where a Mars ascent vehicle is required, a system has been proposed where the propellants are manufactured from Mars atmospheric carbon dioxide and hydrogen brought from earth. The resulting propellant mass produced can be over eighteen times the mass of the supplied hydrogen.

Carbon dioxide is acquired from a simulated Martian atmosphere with a sorption pump using the low Martian night temperatures to drive the adsorption process. The CO₂ is pressurized with the addition of heat from electrical heaters and waste heat from the reactor. The production plant acquired a gas mixture similar to the Martian atmosphere, demonstrating selective adsorption to provide nearly pure CO₂.

Methane and water are produced in a high-efficiency Sabatier reactor where reaction efficiencies higher than 98 percent are routinely achieved. The effective efficiency was boosted to nearly 100 percent with the addition of a novel hydrogen recovery pump which scavenges the residual hydrogen gas from the exhaust stream using well-developed solid-polymer electrolyte technology. The reaction is exothermic and self-sustained operation was achieved with waste heat recovered for driving the sorption compressor.

Water is separated into the constituent hydrogen and oxygen with a solid-polymer electrolyzer. This extremely efficient device also pressurizes the hydrogen for recycling into the reactor, eliminating a mechanical device. The oxygen product is dried and scrubbed of residual CO₂, resulting in nearly pure oxygen suitable for liquefaction.

Production rates for this demonstration plant exceeded 125 grams of liquid oxygen for a six-hour production day. The methane was vented to an analyzer for residual gas measurements. The entire propellant production plant has no moving parts except for valves, suggesting a long operational lifetime. None of the components or subsystems require new technologies or breakthroughs, just further engineering development.

In order to efficiently store the propellants they must be liquefied. The pilot production plant uses a readily available cryocooler to liquefy the entire oxygen output as well as control pressure and eliminate boil-off during non-production periods. Using a precooler to lower the incoming gas to Martian ambient temperatures, the Stirling-cycle cryocooler operated under closed-loop control to maintain Dewar pressure during production and hold periods.

The system was operated with automatic controls which started, stopped and maintained the system. Time-based commands started and stopped the production cycle while conditional sequences controlled the transition modes. Closed-loop controls provide simple, reliable steady-state operation. The system was operated autonomously for four diurnal production cycles, in addition to over twenty five days of developmental test operations with the system.

This in-situ propellant production plant has demonstrated the feasibility of the Sabatier/water electrolysis concept for use on Mars. The simple design, minimal number of moving parts and use of well-developed technologies makes this concept a viable option for Mars sample return missions as well as future manned missions. The system is easily scaleable and realistic mass and power estimates can be generated for any production requirement.